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National Coastal Condition Report III
Chapter 9: Health of Narragansett Bay
for Human Use

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CHAPTER 9

Health of Narragansett Bay for Human Use



Health of Narragansett Bay for Human Use

The previous chapters of this report address the condition of the nation's coasts in terms of how well they meet ecological criteria. A related, but separate consideration is how well coasts are meeting human expectations in terms of the goods and services they provide for transportation, development, fishing, recreation, and other uses. Human use does not necessarily compromise ecological condition, but there are inherent conflicts between human activities (e.g., marine transportation) that alter the natural state of the coasts and activities (e.g., fishing) that rely on the bounty of nature. The emphasis of this chapter is on human uses and how well they are met. For uses that are not being fully met, the question arises as to how the shortfall is related to coastal condition as described by ecological indicators.

Because determining the effect of human uses on an estuary is specific to an estuary's surrounding area and relies on local information,

such an assessment can be pursued only at the level of individual estuaries. The corresponding chapter in the NCCR II centered on Galveston Bay, TX, for this assessment; in this report, the chosen estuary is Narragansett Bay in Rhode Island and Massachusetts. To a large extent, this choice is dictated by the availability of data, and Narragansett Bay is an estuary for which high-quality, long-term data exist on the abundance of commercial and recreational fishes. Although fishing is not the only human use of an estuary, it is an important use that is thought to be strongly connected with ecological indicators.

Overview of Narragansett Bay

Narragansett Bay (Figure 9-1), which includes the Providence and Seekonk rivers, is approximately 48 miles long, 37 miles wide, and 132 mi² in area (Ely, 2002). Although the Bay lies almost entirely within Rhode Island, a small portion of northeastern Mount Hope Bay is located within Massachusetts. The Bay's watershed includes parts of all five Rhode Island counties (Bristol, Kent, Newport, Providence, and Washington) and five counties (Worcester, Middlesex, Norfolk, Bristol, and Plymouth) in Massachusetts. The total area of the watershed is 1,820 mi², and approximately 40% of this area is located in Rhode Island (Ries, 1990; Crawley et al., 2000). The three main rivers that drain into Narragansett Bay are the Pawtuxet, Blackstone, and Taunton rivers.

This chapter will examine the human uses of the Bay (bounded at its seaward end by a line running southwest from Sakonnet Point to Point Judith) and its watershed. Data associated with Block Island and the coast of mainland Rhode Island running along Block Island Sound from Point Judith to the Connecticut state line will not be included in this assessment.



Wickford Harbor on the west shore of Narragansett Bay (courtesy of NBEP).

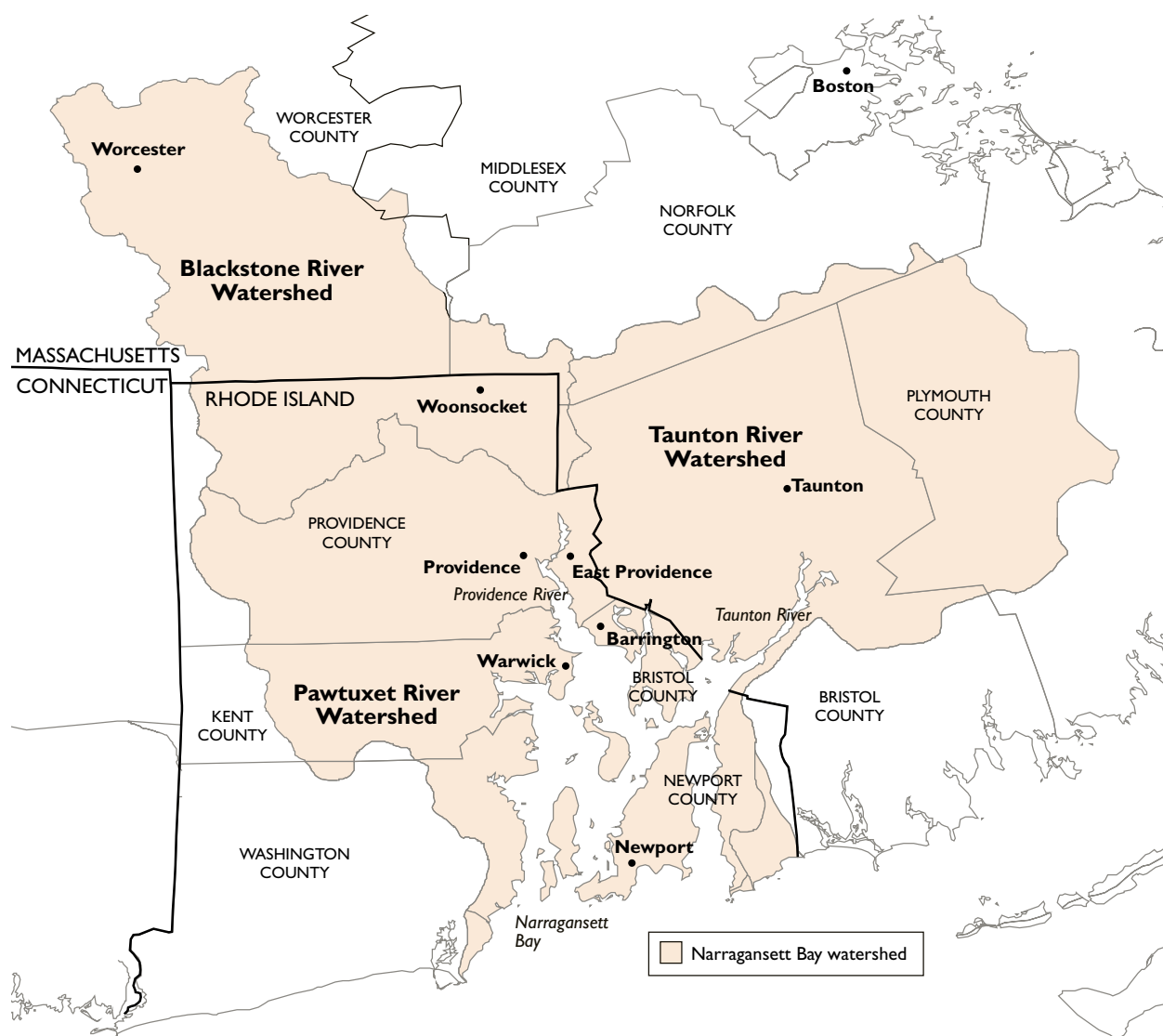


Figure 9-1. The Narragansett Bay watershed and surrounding counties (U.S. EPA/NCA).

Development Uses of Narragansett Bay

Development uses are human activities that alter the natural state of Narragansett Bay and its watershed. Some of the most important of these activities are land use changes and development in the Bay's watershed; marine transportation; and point-source discharges of cooling water and wastewater to the Bay.

Land Use Changes and Development

By the 18th century, a merchant economy had developed to replace agriculture as the primary

economic force in Rhode Island. The deep, sheltered harbors and availability of fresh water helped to spur the transformation of Newport into one of the premier centers for maritime trade and shipbuilding. By the middle of the 19th century, another transformation had occurred: the rivers draining into Narragansett Bay were being used to provide both power and transportation for a rapidly developing industrial economy. Textile mills, metalworking operations, and jewelry manufacturing plants lined many of the watershed's rivers (Crawley et al., 2000); however, by the 20th century, industrial production had declined, in part due to the migration of textile industries to the south. Currently, land use in the Narragansett

Bay watershed is divided among a number of categories (Table 9-1). The largest categories of developed land are residential and agricultural.

Throughout the 20th century, the counties in the Narragansett Bay watershed have been a popular place to live (Figure 9-2). The human population in the watershed doubled between 1900 and 1980. The population of the watershed has moved from urban areas to the more suburban and rural parts of the watershed since 1980 due to the advent of better transportation and changing lifestyles, resulting in a population decline in several cities, including East Providence, Warwick, Newport, Barrington, and Woonsocket in Rhode Island, and Worcester and Taunton in Massachusetts (Burroughs, 2000; Crawley et al., 2000). Although the rate of population growth in Rhode Island has been slow since 1980, residential development, particularly single-family homes, has increased markedly (Rhode Island Department of Administration, 2000). Currently, the watershed's population is estimated at approximately 1.8 million people, and residential land accounts for more than 20% of the area, representing the largest area of any developed land use category in the watershed (Crawley et al., 2000; Save the Bay, Inc., 2006).

Table 9-1. Land Use in the Narragansett Bay Watershed (Crawley et al., 2000)

Land Use	Area (mi ²)	Percent
Residential	216.6	20.1
Agricultural	76.7	7.1
Commercial	20.7	1.9
Recreational	19.4	1.8
Institutional	16.7	1.5
Industrial	13.4	1.2
Transportation and Utilities	10.7	1.0
Roads	10.2	0.9
Commercial/Industrial Mix	2.3	0.2
Urban Vacant	6.9	0.6
Gravel Pits and Quarries	8.4	0.8
Waste Disposal	4.4	0.4
Wetlands, Water, Barren	203.3	18.8
Forest	470.4	43.6

The approximately 77 mi² of farmland in the Narragansett Bay watershed represent approximately 7% of the total land area (Crawley et al., 2000). Major agricultural crops in Rhode Island and Massachusetts include corn and turf. Although Newport County, RI, has the highest percentage (15%) of agricultural area in the watershed, Worcester County, MA, has the greatest number of acres (104,000 acres) dedicated to agriculture (USDA, 2004a; 2004b). It should be noted that these data are presented on a county level and may include agricultural area located within the county, but outside of the Narragansett Bay watershed.

Although the economy of Rhode Island has moved towards a mix of service industries, specialized businesses, and tourism and recreation since World War II, industrial operations remain in the area. Land used for industrial operations accounts for a little over 1% of the land area in the Narragansett Bay watershed (Crawley et al., 2000). According to the Economic Census, the manufacturing industry in Rhode Island produced \$10.5 billion in sales and employed more than 75,000 people in 1997 (U.S. Census Bureau, 2000b). The computer manufacturing and electronics, fabricated metal, electrical equipment and appliances, and textile industry sectors offered the major employment opportunities in the

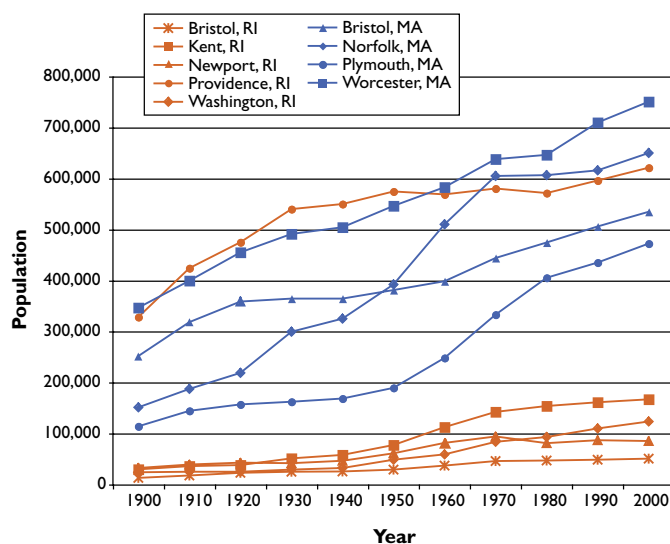
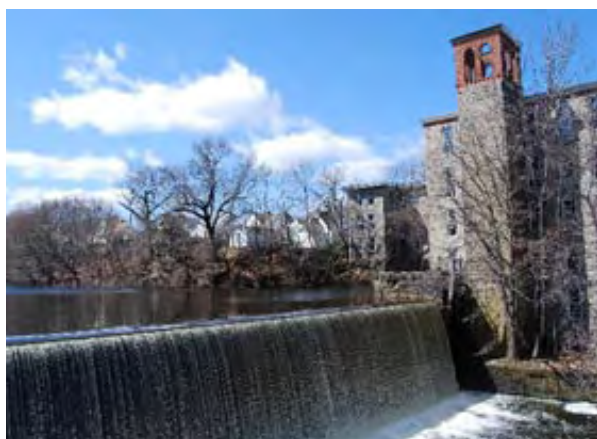


Figure 9-2. Population trends by county in the Narragansett Bay watershed (U.S. Census Bureau, 2001).



Industrial production in the Narragansett Bay watershed developed in the middle of the 19th century (courtesy of Marcabela).

region (U.S. Census Bureau, 2000a; 2000b). For example, manufacturing in Worcester County, MA, accounts for \$11.3 billion annually and employs 61,000 people, primarily in computer, metal fabrication, and chemical manufacturing. In Bristol County, MA, computer, electronics, and primary metal manufacturing activities accounted for \$7.7 billion in 1997 and employed more than 49,000 people (U.S. Census Bureau, 2000a).

Marine Transportation

Marine transportation is integral to the economy of Narragansett Bay. There are two main shipping channels (Providence River and Quonset/Davisville) and three public ports (Providence, Fall River, and Quonset/Davisville). The majority of commercial marine vessels entering Narragansett Bay carry petroleum products. In 1997, 86% of the 8.78 million t of cargo entering Narragansett Bay were petroleum products, primarily fuel oil and gasoline carried on barges. Cruise ships and ferries are also an important part of the economy of Narragansett Bay, and the number of cruise ships heading to Newport, RI, has increased since 1994 (Anderson et al., 2000).

Recently, the citizens of Rhode Island were faced with three marine transportation issues. Since last dredged in 1971, the Providence Ship Channel had become so shallow and narrow that the U.S. Coast Guard restricted the passage of two-way ship traffic and deep-draft vessels in the upper portion of the Channel located within the Providence

River. As a result of these restrictions, petroleum products had to be transferred from tankers onto barges before delivery to Providence Harbor. Dredging was required to return the Channel to its authorized 40-ft depth and to increase the efficiency of marine transportation to the Harbor. After some debate, dredging operations began in April 2003 and were completed in January 2005, resulting in the removal of 6 million cubic yards of sediment (USACE, 2001; 2005). A second issue concerned the development of a container ship terminal at the former U.S. Naval facility at Quonset Point in North Kingstown (Ardito, 2002). The project was dropped in 2003, and other plans are being developed for the area. Finally, there have been a number of proposals to develop liquid natural gas (LNG) terminals at various locations in Narragansett Bay. Safety, security, and environmental concerns have been raised over the transport and storage of LNG.

Point-Source Discharges

Narragansett Bay is also used to receive point-source discharges of cooling water, industrial wastewater, and municipal wastewater. EPA reports that there are more than 40 major point-source dischargers in the Narragansett Bay watershed (Figure 9-3) (U.S. EPA, 2005c). The largest of these dischargers is the Brayton Point power plant in Somerset, MA. Brayton Point is the largest fossil-fuel power plant in New England and produces approximately 6% of the region's electricity (Ardito, 2002). This plant uses approximately 800 million gallons of water from the Bay per day as cooling water; after the water is used, warm water is discharged to the Bay. Studies have shown that the discharge of heated water from the Brayton Point facility to the Bay has contributed to the collapse of the Mount Hope Bay winter flounder fishery. In recognition of this possible conflict between competing human uses, renewal of the plant's discharge permit contains provisions to decrease water withdrawals from the Bay by 94% and reduce the annual heat discharge by 96% (U.S. EPA, 2003). The next-largest point-source facility in the watershed is the Dominion Energy power plant in Providence, RI, with a discharge flow of approximately 260 million gallons per day (U.S. EPA, 2005c).

Wastewater from industrial and municipal sources is also discharged from point sources located within the Narragansett Bay watershed. A number of paint/pigment manufacturers, seafood processors, and petroleum bulk stations and terminals operate in Rhode Island and discharge industrial wastewater to the Bay and its watershed. The majority of the other large point-source dischargers are WWTPs. There are ten major WWTPs in the watershed, with design capacities of more than 10 million gallons per day; three plants are located in Massachusetts (Worcester, Brockton, and Fall River), and seven are located in Rhode Island (Field's Point [Providence], Bucklin's Point [East Providence], East Providence, Cranston, West Warwick, Woonsocket, and Newport) (U.S.

EPA, 2005c). Although the total population of the watershed has continued to increase, the number of area residents using these WWTPs has remained steady over the past 30 years (Nixon et al., 2005).

Industrial and municipal wastewater can contribute heavy metals to the Bay. In the context of detailing metal inputs to Narragansett Bay, Nixon (1995) described the history of development and industrialization in Rhode Island from colonial times to the present. Metal inputs began to decline remarkably after about 1960. Some of this decrease can be attributed to the state's changing economic base, but increasing controls on metal releases from a variety of sources, upgrades to STPs, and the cessation of sewage sludge dumping in the Bay has also contributed to the decline (Nixon, 1995).

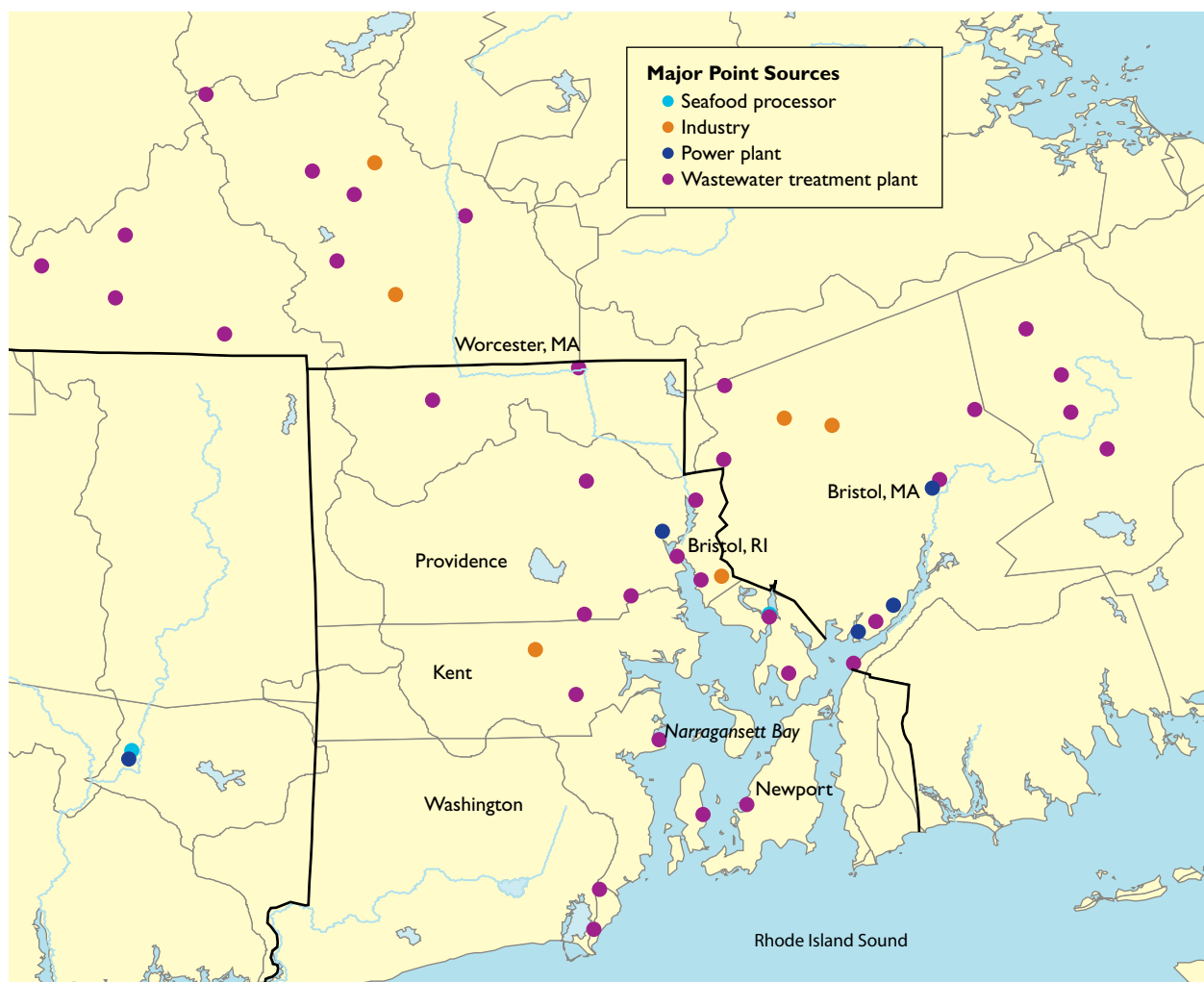


Figure 9-3. Major point sources in the Narragansett Bay watershed (U.S. EPA, 2005c).

Nitrogen and phosphorus are other pollutants that can enter the Bay through point-source discharges of industrial and municipal wastewater. Nixon et al. (2005) examined nitrogen and phosphorus inputs to the Bay from the direct discharge of municipal wastewater, as well as inputs from some of the Bay's tributaries, which can provide insight into contributions from upstream point and non-point sources of nitrogen and phosphorus (including WWTPs). Overall, nitrogen inputs to the Bay have not increased in recent decades, and phosphorus inputs have decreased. The study also concluded that these tributaries contributed 1.5 times more nitrogen and 2.7 times more phosphorus than the combined discharges from the area's three largest WWTPs (Nixon et al., 2005); however, a large portion of the nutrient load to these tributaries comes from other municipal WWTPs.

Nutrients, including nitrogen and phosphorus, support vegetative growth and are essential to marine life; however, high levels of nutrients can lead to excessive vegetative growth. The subsequent decay of this plant matter consumes oxygen and lowers dissolved oxygen concentrations in the

waterbody. Bergondo et al. (2005) and Deacutis et al. (2006) found that summer oxygen measurements in both deep and shallow waters in certain areas of upper Narragansett Bay can drop below 2 mg/L (a level that is intolerably low to some organisms even when maintained over short periods [hours]). These hypoxic conditions are due to nutrient-induced algal growth coupled with the lower mixing rates that occur during neap tides, which are periods of low wind and strong stratification that isolate deep water from surface waters. Bergondo et al. (2005) also reviewed dissolved oxygen measurements collected since 1959 during summertime neap tides in the deep waters of upper Narragansett Bay. Low dissolved oxygen concentrations (< 3 mg/L) were only observed in 18% of the measurements, indicating that the presently observed conditions are likely a relatively new feature of Narragansett Bay. Further information on dissolved oxygen levels in Narragansett Bay is available at <http://www.geo.brown.edu/georesearch/insomniacs>. In recognition of the low oxygen levels in the upper Bay and their connection with nutrient levels, the Rhode Island Department of Environmental Management (RIDEM) has initiated a program to reduce nitrogen concentrations in effluent from WWTPs (RIDEM, 2005b).



The Rose Island Lighthouse is located in the southern portion of the Narragansett Bay, near Newport, RI (courtesy of NBEP).



Highlight

Summer Dead Zone Kills Billions of Narragansett Bay Mussels

During the summer of 2001, low dissolved oxygen levels (hypoxia) caused fish kills, foul odors, and closed beaches throughout Narragansett Bay (Lawton, 2006). At the same time, scientists discovered a massive die-off of blue mussels (*Mytilus edulis*), which are a foundation species and vital to the health of the Bay. Oxygen depletion in bottom waters suffocates sea life, particularly sedentary bottom dwellers that are unable to leave the area, such as the blue mussels. These species are frequently keystones of coastal ecosystems, providing water filtration and circulation, as well as habitat for other species (Altieri and Witman, 2006). As they filter the water, these sedentary bottom dwellers consume phytoplankton or algae, and the declines in bivalve populations may result in the inability to avoid future hypoxic events caused by algal blooms.

Increased nutrient levels from sources such as fertilizer applications, sewage spills, or septic tanks can initiate hypoxic events in estuarine waters. Paired with warm summer temperatures and a lack of water circulation, nutrient pulses to the estuary create ideal conditions for exponential increases in phytoplankton populations, resulting in massive algal blooms. As the algae from the blooms die and sink to the bottom, bacteria consume them along with dissolved oxygen, creating hypoxic areas or “dead zones” in estuarine bottom waters (Lawton, 2006).

By consuming phytoplankton, suspension feeders such as bivalve mollusks (e.g., blue mussels) have the potential to help control the eutrophication that ultimately fuels the development of hypoxic events (Officer et al., 1982); however, bivalves are frequently the casualties of hypoxia due to their sedentary nature. When hypoxia reduces bivalve populations, the bivalves filter less water and consume less phytoplankton. A decreased filtration capacity may lead to increased occurrences of hypoxia and further mortality of these suspension feeders; therefore, these catastrophic hypoxic events and their resulting localized extinctions may trigger a downward spiral, with coastal zones less able to cope with environmental degradation (Altieri and Witman, 2006).

One month before the 2001 hypoxia event occurred, surveys of nine mussel reefs in Narragansett Bay revealed healthy, densely packed mussels covering the sea floor. As the summer progressed, researchers noted the greatest reductions in mussel densities on reefs where bottom-water dissolved oxygen concentrations were lowest. One of the nine reefs studied experienced complete mussel extinction, and seven more were severely depleted. Approximately 4.5 billion mussels, about 80% of the reefs' populations, died that summer. In the fall of 2002, one year after the die-off event, the mussel population on only one of the nine reefs was recovering (Altieri and Witman, 2006).

In order to help assess the effects of the die-off on the Bay, Altieri and Witman (2006) calculated the filtering capacity of mussels on the reefs. Before the 2001 hypoxic event, healthy mussel populations took approximately 20 days to filter the equivalent of the entire water volume of Narragansett Bay. During the summer of 2001, the filtering capacity of the nine mussel reefs studied declined by more than 75%, increasing the number of days needed to filter the volume of the Bay to approximately 79 days (Altieri and Witman, 2006). With the mussel population and its filtering capacity severely depleted, Narragansett Bay may lose the ability to prevent future dead zones from forming. Dead zones have occurred in Southeast Coast estuaries as a result of the near extinction of oysters (*Crassostrea virginica*), which in turn contributed to further hypoxia and failure of oyster populations to recover (Ulanowicz and Tuttle, 1992; Lenihan and Peterson, 1998).

The loss of a foundation species such as the blue mussel, which filters water and provides food and habitat for other estuarine organisms, can have a significant, long-lasting effect on the local Narragansett Bay ecosystem; however, it is not an isolated incident. According to a 2004 United Nations Environment Programme report (UNEP, 2004), the number of coastal areas affected by hypoxia worldwide has doubled since 1990. Dead zones similar to those experienced in Narragansett Bay can also be found along the East Coast of the United States, in European coastal waters, and off the coasts of Australia, Brazil, and Japan. One of the largest dead zones occurs annually in the Gulf of Mexico near the mouth of the Mississippi River Delta, where the hypoxic zone has been known to extend along the coastline covering up to 8,500 mi², an area the size of New Jersey (Rabalais et al., 2002).



When excess nutrients are introduced to poorly flushed waters, massive algal blooms, such as this dense green macroalgal bloom near Warwick, RI, can occur. These blooms can initiate hypoxic events in estuarine waters (courtesy of Giancarlo Cichetti, IAN Network).

Amenity-Based Uses of Narragansett Bay

Amenity-based uses depend on the natural resources of Narragansett Bay and include accessing the shoreline, swimming, boating, and commercial and recreational fishing. Over time, many of these uses have been impacted by human activities and population pressures in the watershed.

Amenity-based uses contribute economic and recreational value to the area's residents. For example, more than 12 million people visit the Bay area each year, contributing to the area's major tourism industry (Save the Bay, Inc., 2006). In 1998, this industry was second only to health services in terms of total wages for the area, and 30% of tourism was associated with amenity-based uses of Narragansett Bay (Colt et al., 2000). Colt et al. (2000) estimate that the great economic value of the Bay's tourism industry is probably far exceeded by its recreational value to area residents.

Public Access

The Rhode Island Constitution (Article I, Section 17) states that "The people shall continue to enjoy and freely exercise all rights of fishery, and privileges of the shore, to which they have been heretofore entitled under the charter and usages of the state... 'Privileges of the shore' include 'fishing from the shore, the gathering of seaweed, leaving the shore to swim in the sea, and passage along the shore.'" Nonetheless, Bay access is limited because most of the area landward of high tide is privately owned. Although there are 16 miles of public beaches, most of the Bay's 256-mile shoreline is not publicly accessible (Colt et al., 2000; Ely, 2002; Allard Cox, 2004). Of the 80 licensed beaches along Narragansett Bay, 10 are operated by the state or a town and 70 are privately owned (RIDOH, 2005). Some of the private and town-owned beaches are open to the public for a fee. In 1978, the Rhode Island Coastal Resources Management Council (CRMC) began to establish public rights-of-way to the coast. Of the 252 locations described in the guidebook *Public Access to the Rhode Island Coast* (Allard Cox, 2004), 191 access rights-of-way routes established by the CRMC cross otherwise private lands to areas where, depending on the particular

right-of-way, the public can reach areas for viewing nature; fishing; swimming; or launching a boat.

Beaches

Bacterial contamination in Narragansett Bay has resulted in periodic closures of licensed private and public beaches. These closures are due to exceedances of bacterial standards and are generally associated with stormwater runoff after rainstorms in the northern, more populated part of the Bay. For example, episodic closures occur near Providence due to overflows from combined storm and sanitary sewers. In other areas, periodic closures occur due to spills. Table 9-2 lists the number of licensed beaches in each county and the number of closings/ advisories issued for 2001 to 2004. The Rhode Island Department of Health maintains a Web site (<http://www.ribeaches.org/closures.cfm>) listing current beach closures. In addition, a general advisory has been issued to discourage swimming and other full-body contact activities in the Providence River portion of upper Narragansett Bay because "These waters are directly affected by pollution inputs due to heavy rains and discharges from area wastewater treatment facilities. Water contact should be avoided for a minimum of 3 days after heavy rainfall" (RIDOH, 2005). A combined sewer overflow (CSO) project is underway in Providence to create a tunnel that will divert up to 62 million gallons of storm water for later treatment rather than allowing it to flow directly into the Bay (Samons, 2002).



Boating is a popular pastime, but the number of slips and moorings in Narragansett Bay has not risen in proportion to boat registrations (courtesy of Chris Deacutis).

Table 9-2. Total Number of Licensed Beaches and Closure/Advisory Days (NRDC, 2005)

County	Number of Beaches	Closure/Advisory Days			
		2001	2002	2003	2004
Providence	1	15	6	0	38
Bristol	4	4	9	132	16
Kent	4	26	67	55	3
Newport	18	13	21	39	192
Washington*	44	4	0	79	2
Total	71	62	103	305	251

*Washington County beaches include those along Rhode Island Sound.

Boating

The number of registered boats in Rhode Island increased from about 29,000 in 1993 to 41,000 in 2002 (NBEP, 2002), and it is probably fair to assume that most are used in Narragansett Bay. In 1988, there were 13,500 slips and moorings in Narragansett Bay (Colt et al., 2002). New docks and marinas are disallowed along 70% of the statewide Rhode Island shoreline, and the number of slips and moorings has not risen in proportion to boat registrations (Rhode Island CRMC, 1996; Liberman, 2005). As a result, most boaters in Narragansett Bay must tow boats to one of the 32 public or 12 private boat ramps, many of which have no or limited space for parking cars and trailers (Allard Cox, 2004; RIDEM, 2005c).

Fishing

Fishing is a popular and rewarding recreational and commercial activity in Narragansett Bay. Although the Bay supports commercial and recreational fishing, the species sought and landed have changed over time.

Commercial Fishing

In 1880, Narragansett Bay supported a variety of commercial fisheries, including alewife, tautog, scup, lobster, and winter flounder. As time passed, however, the Bay's commercial fisheries grew smaller as offshore fishing increased. By the 1960s, Narragansett Bay no longer supported a large commercial finfish fishery (Oviatt et al., 2003). Currently, the annual commercial fish catch for Rhode Island fetches more than \$70 million (RIDEM, 2005a). The great bulk of these commercial landings consists of fish caught in Rhode Island Sound or further offshore; however,

Narragansett Bay remains commercially important for shellfish. An estimated 10–20% of Rhode Island's total lobster landings are caught in the Bay (Ely, 2002). In addition, the state's quahog fishery is contained mostly within the Bay, with average landings of 1.5 million pounds for the period 1990–2004 and a value of \$7.5 million (NOAA, 2005a).

Although the causes for many of the declines in the Narragansett Bay fisheries are unknown, some of them can be traced to changes in environmental conditions (Ardito, 2003; Oviatt et al., 2003). For example, habitat loss can play a key role in fisheries decline. Eelgrass beds are critical habitat for bay scallops. Narragansett Bay once supported a large, commercial bay scallop fishery. In 1880, more than 300,000 bushels of bay scallops were harvested from Narragansett Bay, a quantity that would be worth more than \$33 million on today's wholesale market; however, in 2003, the bay scallop landings from the Bay were nonexistent. The loss of this fishery can be traced to the loss of the scallop's habitat—eelgrass beds (Ardito, 2003). Eelgrass beds were widespread in Narragansett Bay as late as the 1860s, and historical accounts record eelgrass beds at the head of the Bay in the lower Providence River. During the 1930s, wasting disease—a widespread infection partly attributed to the slime mold *Labryinthula zosterae*—decimated Atlantic coast eelgrass populations, including those in Narragansett Bay (Short et al., 1987). The Bay's eelgrass beds continued to shrink throughout the 20th century, due largely to decreased light penetration from nutrient pollution and algal growth (Ardito, 2003; Lipsky, 2003). Approximately 100 acres of eelgrass remain in Narragansett Bay today (Save the Bay, Inc., 2006). Many former scallop-harvesting areas of the Bay now support the quahog fishery (Ardito, 2003).

Recreational Fishing

About 300,000 sport anglers seek finfish and shellfish in Rhode Island's marine waters (RIDEM, 2005a). Since 1981, the NMFS has maintained a database (NOAA, 2005d) containing information gathered from a survey on recreational catches. It should be noted that this database shows data on a statewide level and combines catches in the Bay with those reported in Rhode Island's sounds. In the 24-year period from 1981 to 2004, the NMFS recreational survey showed that the total number of fish caught annually fluctuated with no overall trend (Figure 9-4). The median recreational catch since 1981 has been 2 million fish, and nine species have been among the five most commonly reported recreationally caught fish in any given year (Table 9-3) (NOAA, 2005d). On the basis of information from the RIDEM, an estimated one-third to one-half of the state's recreational catch is taken from within the Bay as opposed to Rhode Island Sound, Block Island Sound, or areas further offshore (Ely, 2002). Narragansett Bay's recreational fishery is estimated at more than \$300 million per year (NBER, 2006).

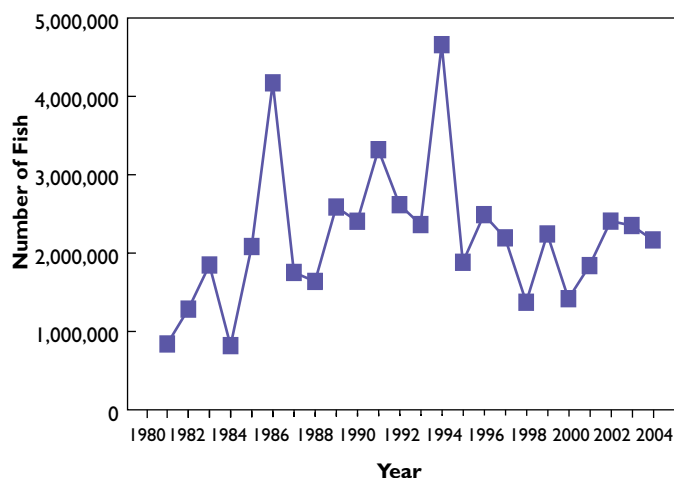


Figure 9-4. Recreational fish catches in Rhode Island by year (NOAA 2005d).

Table 9-3. The Most Commonly Reported Recreationally Caught Fish in Rhode Island Between 1981 and 2004 (NOAA, 2005d)

Fish Species	Number of Years Listed in the Top 5
Bluefish	24
Scup	24
Winter flounder	11
Striped bass	10
Summer flounder	10
Tautog	10
Herrings	6
Cunner	7
Atlantic mackerel	5

Estimates of Fish and Shellfish Abundance

Data from systematic trawls and estimates of recreational fish landings have been used to monitor shifts in species abundance in Narragansett Bay. The University of Rhode Island (URI) has maintained a weekly fish trawl at Fox Island since the 1960s (Oviatt et al., 2003). RIDEM has also conducted fishery-independent estimates of fish abundances in the Bay using biannual (spring and fall) systematic trawling of Narragansett Bay, Rhode Island Sound, and Block Island Sound. Starting in 1990, the Narragansett Bay biannual trawling was augmented with monthly trawling at 12 stations randomly selected from a pre-set grid (Lynch, 2005). The NMFS recreational survey database (NOAA, 2005d) supplies information on recreation landings in Rhode Island, and these data are used in conjunction with trawl data to provide additional insight into shifts in species abundance.

The species that dominated the URI weekly fish trawl at Fox Island in the 1960s and 1970s were sea robins, winter flounder, and windowpane flounder. These species comprised a much smaller portion of the catch in the 1980s and a very small portion in the 1990s. The opposite trend was observed for crabs and lobsters, which were a very small part of the total in the 1960s, but grew to dominate the Fox Island catch in the 1990s (Oviatt et al., 2003).

Figure 9-5 and Table 9-4 combine data on annual numbers of fish taken in RIDEM biannual trawl surveys with the recreational catch numbers from the NMFS database. It should be noted that these two sets of data were collected over different geographic regions. The RIDEM data used in this

analysis were collected in Narragansett Bay, whereas the NMFS data set includes recreational landings from Rhode Island coastal sounds. This comparison is not ideal, but is necessary because NMFS does not segregate their data to distinguish landings in Narragansett Bay from those outside of the Bay.

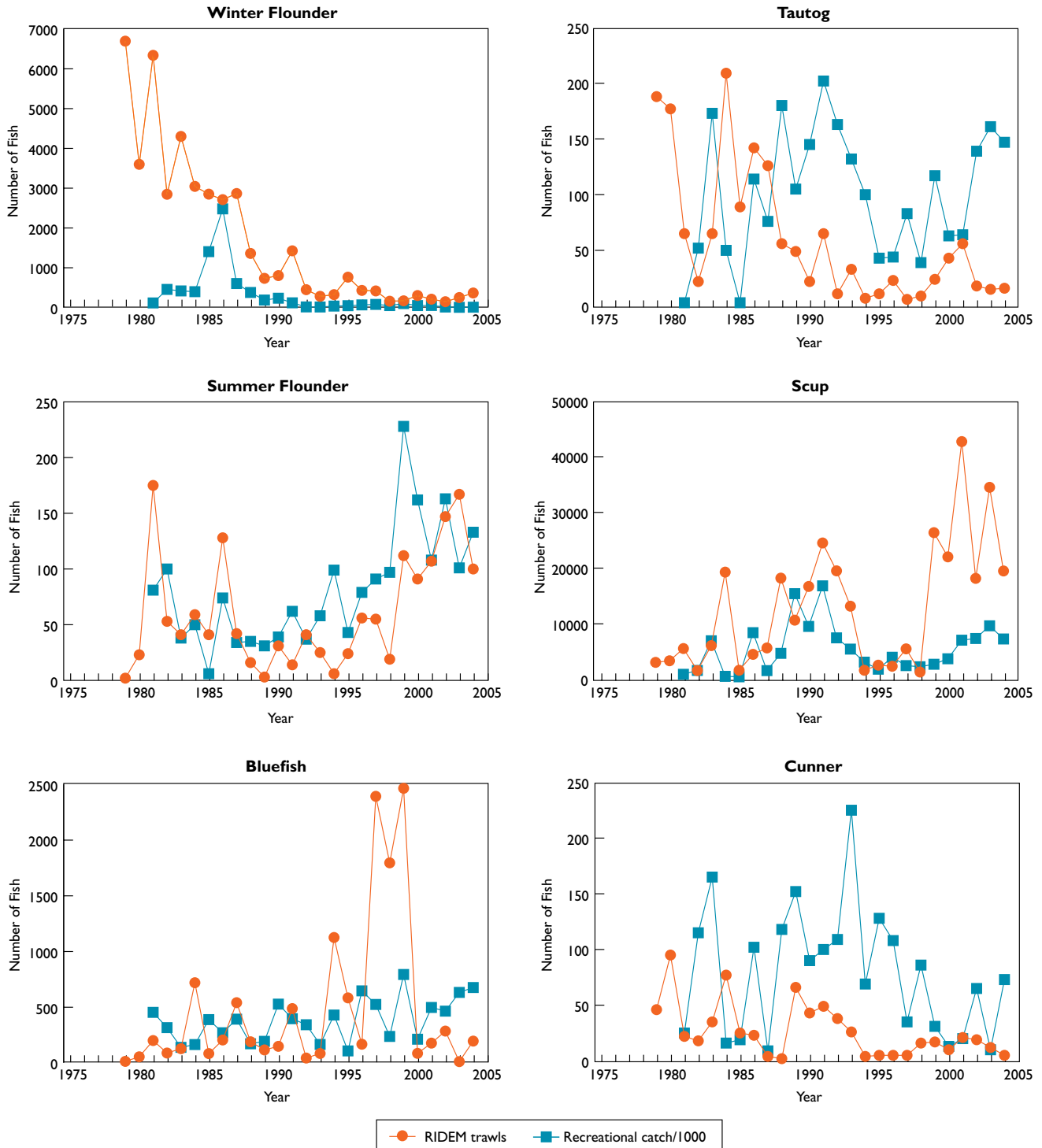


Figure 9-5. Number of fish of six species annually taken in RIDEM trawls in Narragansett Bay and number reported by recreational anglers to NMFS in Narragansett Bay and the Rhode Island coastal sounds (based on data from Lynch, 2005 and NOAA, 2005d).

Table 9-4. Comparison of the Most Commonly Harvested Fish Species during RIDEM Trawls Conducted from 1979–2004 in Narragansett Bay, and Recreational Fishing Efforts Reported to NMFS from 1981–2004 in Narragansett Bay and the Rhode Island Coastal Sounds (Lynch, 2005; NOAA, 2005d)

Species	RIDEM		Recreational ^a	
	Median (number of fish)	Trend ^b	Median (number of fish)	Trend ^b
Bay anchovy	31,000	—	none	—
Scup	8,400	—	440,000	—
Longfin squid	3,800	—	none	—
Butterfish	2,600	I	none	—
Winter flounder	750	D	89,000	D
Weakfish	470	—	1,700	D
Atlantic herring	440	I	70,000	I
American lobster	350	—	none	—
Bluefish	180	—	39,000	—
Skates	190	—	13,000	—
Windowpane flounder	120	D	none	—
Alewife	80	I	none	—
Atlantic moonfish	72	I	none	—
Blueback herring	60	—	** ^c	—
Red hake	56	D	none	—
Summer flounder	42	—	77,000	I
Tautog	38	D	100,000	—
Spotted hake	26	—	none	—
Cunner	20	D	79,000	—
Striped searobin	20	—	16,000	—
Striped bass	0	I	85,000	I
Atlantic mackerel	0	—	29,000	—

^a Recreational landings included fish caught in Rhode Island and Block Island sounds.

^b Trends are indicated as increasing (I) or decreasing (D) if Spearman rank correlation coefficient between numbers of fish and year was greater than 0.5 or less than -0.5, respectively.

^c Blueback herring are probably included in the recreational landings for “herring.”

The graphs in Figure 9-5 plot the annual numbers of six species commonly caught by the RIDEM trawls and the landings by recreational anglers from the NMFS database. These graphs reflect the large year-to-year variability in annual catch data, which is characteristic of many species, and provide the opportunity to evaluate the different results obtained using the two sampling methods: trawls (RIDEM) vs. recreational hook-and-line fishing (NMFS). Table 9-4 displays data for the 20 species with the highest median annual RIDEM trawl

catch numbers over the 1979–2004 time period and for the 12 species that were most commonly taken by recreational anglers between 1981 and 2004. Some of the commonly trawled species are not taken by recreational anglers, and the median NMFS recreational catch numbers for these species are listed as “none” in the table. Conversely, two of the species commonly taken by anglers (striped bass and Atlantic mackerel) are often absent in RIDEM trawls (medians of zero indicate that no fish of that species were collected during more than half

of the years). Table 9-4 also shows whether trawl catch or recreational landing numbers exhibited an increasing (I) or decreasing (D) trend over the time period. Although this correlation was an objective definition of trends, similar conclusions can be made by simply looking at the time series in Figure 9-5 for several of the species (i.e., winter flounder, tautog, and cunner catches are decreasing, whereas summer flounder are increasing). It should be noted that the species and data listed in Table 9-4 are based on long-term data sets; therefore, species exhibiting large catch numbers over the short term were excluded. For example, menhaden were present at high numbers (median of 9,800 fish) in RIDEM trawls collected between 1999 and 2004; however, this species does not appear in Table 9-4 because the median number of fish collected in trawls over the long-term (1979–2004) is only 18. Furthermore, although long-term data may show decreasing trends, some individual species (e.g., tautog, winter flounder) may be increasing over shorter time scales (i.e., 2001 to 2006) (personal communication, Lynch, 2006).

All of the fish species caught in Narragansett Bay forage in the Bay, and some of these species also spawn in the Bay; however, most species spawn offshore and move into the Bay as part of

their annual migration. The species that spawn in Narragansett Bay would seem to be most sensitive to environmental quality in the Bay. Two of the species that spawn in the Bay (i.e., tautog and winter flounder) are recreationally important and have exhibited decreasing abundances. In addition to fishing pressure, tautog and winter flounder population declines are possibly related to the summertime hypoxia reported in the upper portions of the Bay (Bergondo et al., 2005; Deacutis, In press), but these declines could also be related to large-scale environmental changes unrelated to any human use of Narragansett Bay. For example, species shifts in parts of North America and Europe have been correlated with cyclic climate changes induced by the North Atlantic Oscillation (Drinkwater et al., 2003). In addition, a steady rise in sea surface water temperature has been observed since the mid-1960s in the coastal waters of the northeastern United States (Nixon et al., 2004). If these temperature patterns are representative of the water column as a whole, winter flounder populations could be impacted. Under experimental conditions, warmer water decreased the survival rates of winter flounder eggs. These results were attributed to increased predation on the eggs by sand shrimp (Keller and Klein-MacPhee, 2000; Taylor and Danila, 2005).



Newport Bridge, RI (courtesy of NBEP).

Fishery Restrictions

Regardless of the cause for decreasing abundance of any species, removal of fishing pressure should benefit the population. The abundance of winter flounder is so low in Narragansett Bay that recreational or commercial harvest of this species is prohibited in parts of the Bay (RIDEM, 2005a). Because high concentrations of bacteria indicative of mammalian fecal material were found in water and in mollusks that are often eaten raw, 34% of the Bay was permanently closed to shellfishing in 2005 and another 16% was closed for some period after rainfall events (RIDEM, 2005a). In the absence of these closures, the quahog landings may have been greater.

Narragansett Bay encompasses estuarine and coastal areas in both Rhode Island and Massachusetts. Although no waterbody-specific fish advisories are in effect for Narragansett Bay, both of these states have issued fish consumption advisories for all estuarine and coastal waters within their respective jurisdictions, including the waters of Narragansett Bay (U.S. EPA, 2005b). Table 9-5 summarizes the fish consumption advisories covering Narragansett Bay and includes information on the contaminants for which the

advisories have been issued, the fish and shellfish species covered in the advisory, and the population (general population or sensitive subpopulation) for whom the advisory has been issued.

Fish consumption advisories are issued based on the level of chemical contaminants detected in the fish tissue. The PCB advisories have been in effect since 1993 (Rhode Island) and 1994 (Massachusetts), whereas the mercury advisories were first issued in 2001 (Massachusetts) and 2002 (Rhode Island). For two popular recreational species, striped bass and bluefish, the states advise sensitive populations against consuming any of these fish because of the levels of mercury and total PCB concentrations in their tissues (Rhode Island) or because of PCBs in their tissues (Massachusetts). In addition, the State of Massachusetts advises all members of the general population against consuming the heptatop pancreas tissue (tomalley) of lobster because of elevated concentrations of PCBs in this tissue. The State of Rhode Island also recommends that members of the general population limit consumption to one meal per month of striped bass because of the PCB levels in this fish tissue (U.S. EPA, 2005b). In addition, a commercial fishing ban was in effect for all striped

Table 9-5. Fish Consumption Advisories in Effect for Narragansett Bay in 2004 (U.S. EPA, 2005b)

State	Chemical Contaminant	Populations Targeted by the Advisory	Fish Species Under Advisory
Massachusetts—all estuarine and coastal marine waters	Mercury	NCSP	King mackerel Shark Swordfish Tilefish Tuna (steaks)
		NCSP	Bluefish
	PCBs	NCGP	Lobster (tomalley)
Rhode Island—all estuarine and coastal marine waters	Mercury	NCSP	Striped bass Bluefish Shark Swordfish
		NCSP	Striped bass Bluefish
	PCBs	RGP	Striped bass
		CFB	Striped bass 26–37" in length*

NCSP=No-consumption recommended for sensitive populations (pregnant and nursing women and children)

NCGP=No-consumption recommended for the general population

RGP=Restricted consumption for the general population to one meal/month

CFB=Commercial fishing ban

*This ban has since been lifted (personal communication, Deacutis, 2006)

bass from 26–37 inches in length (U.S. EPA, 2005b); however, this ban has since been lifted (personal communication, Deacutis, 2006).

It is important to note that fish advisories are issued by state governments; therefore, some differences between state advisories may occur in estuarine areas that span state borders. It should also be understood that many species of fish, such as striped bass and bluefish, are highly migratory in nature. The mercury and PCB concentrations bioaccumulated in the tissues of these species are not solely derived from chemical contamination in Narragansett Bay, but have been accumulated from exposure to contamination along the species' migratory routes, which include many of the estuaries and coastal areas of the Northeast.

Are Human Uses Being Met by Narragansett Bay?

Human uses are being met by Narragansett Bay; however, as with most any other estuary, there are some limitations. Development uses are presently met, but there is controversy. Earlier plans to build a container ship terminal at Quonset Point have been dropped, but plans are being pursued to develop LNG terminals at various locations in Narragansett Bay. In order to decrease the frequency and spatial extent of summertime hypoxia in the deep waters of the upper Bay, nitrogen inputs are being reduced by increasing the level of treatment required at WWTPs from secondary to tertiary treatment.

Rhode Islanders and tourists relish the Bay's natural amenities. The shoreline is public in Rhode Island, and while ready access to most of it is enjoyed by property owners, an increasing number of public access points are being established. Boat registrations indicate that the popularity of boating is on the rise; however, participants in this activity would benefit from improved access points. The availability of slips and mooring space has not kept pace with the rise in boat registrations, and many of the shore access points do not have parking space for boat trailers.

Bacterial contamination causes periodic beach closures and is the basis of a permanent advisory against recreational water contact in the Providence

River. Closures generally occur after storm events carry runoff into the Bay. In Providence, a CSO project is proceeding to capture storm water before it enters the Bay. The successful completion of this project may lead to the removal of a permanent advisory against recreational water contact in some areas. Bacteria are also the cause of permanent shellfish bed closures in over 34% of Bay waters, with an additional 16% of the area closed after storms. These closures are effectively removing some predation on quahogs in the closed areas, and these populations may be serving as the seed stock to sustain the quahog fishery in the rest of the Bay (Oviatt et al., 2003).

The Rhode Island commercial fishery has moved offshore during the past 50 years. With the exception of the quahog and small lobster fisheries, the Bay no longer supports a major commercial fishery; however, the recreational fishery attracts over 300,000 anglers each year and is a major part of Rhode Island's tourist industry. Although winter flounder dominated the recreational catch in the early 1980s, the abundance of this species has been decreasing since the late 1980s, and there is a current ban on harvesting winter flounder in most of the Bay. The total annual number of all fish species harvested recreationally has been relatively constant (no positive or negative trend), and the decrease in the catch of demersal fish (e.g., winter flounder, tautog) has been countered by the increase in catch of summer flounder and pelagic fish (e.g., bluefish, striped bass). Because the total recreational catch has remained relatively constant, winter flounder population declines have not decreased the overall value of Narragansett Bay to recreational anglers.

Although recreational catches remain relatively constant in the Bay, fish advisories first issued for PCBs in the 1990s and for mercury in the early 2000s remain in effect. These advisories recommend that sensitive populations (e.g., pregnant and nursing women, young children) not consume any of the listed species from the Bay. In addition, advisories in effect for the general population recommend no consumption of lobster tomalley (Massachusetts) and restricted consumption of striped bass (Rhode Island). These advisories restrict uses of Narragansett Bay's fishery resources.

Human Uses and NCA Environmental Indicators

As reported in the NEP CCR (U.S. EPA, 2006b), the overall condition of Narragansett Bay is rated poor based on the four NCA indices of estuarine condition (Figure 9-6). The water quality index for Narragansett Bay is rated fair, the benthic index is rated fair to poor, and the sediment quality and fish tissue contaminants indices are both rated poor. Figure 9-7 provides a summary of the percentage of estuarine area in good, fair, poor, or missing categories for each parameter considered. Please refer to Chapter 1 for a summary of the criteria used to develop the rating for each index and component indicator. This environmental assessment is based on data from 56 NCA sites sampled in the Narragansett Bay estuarine area in 2000 and 2001.

In general, the water quality, sediment quality, and benthic index data demonstrate a north-to-south gradient, with poorer conditions found in the northern, more populated portion of the estuary. These findings are consistent with the human uses being compromised in the same portion of the Bay. The fish tissue contaminants index was rated poor for 91% of the fish and shellfish samples collected from the Bay, and all whole-fish samples surveyed contained quantities of PCBs that exceeded or fell within EPA's Advisory Guidance values for fish consumption. These results were consistent with the fish advisories issued for the Bay. It should be noted that migratory fish species can bioaccumulate contaminants across a wide geographic range; therefore, high contaminant concentrations measured in fish collected in Narragansett Bay are not necessarily indicative of high levels of pollution in the Bay. This index is best examined in context with other environmental indicators.

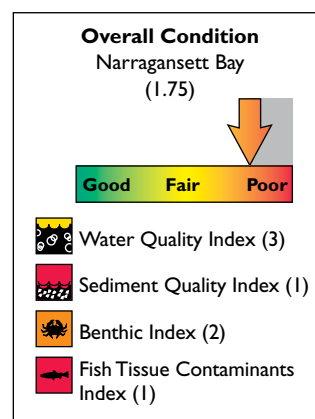


Figure 9-6. The overall condition of the Narragansett Bay estuarine area is poor (U.S. EPA/NCA).

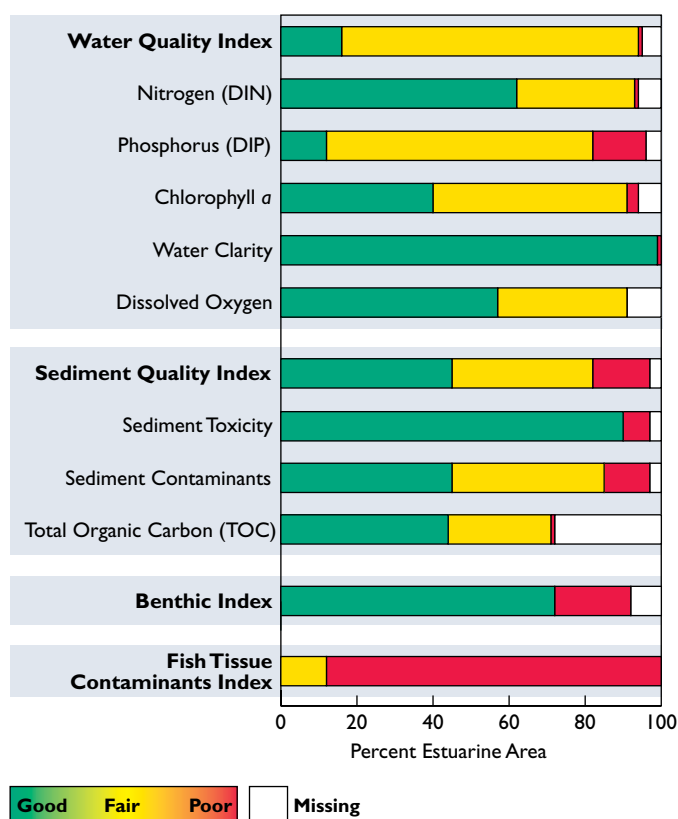


Figure 9-7. Percentage of estuarine area achieving each rating for all indices and component indicators—Narragansett Bay (U.S. EPA/NCA).